AD-A268 506

Final Report
ONR Grant N00014-90-J-1828
Submitted by L. Gary Leal

During the 1990 fiscal year, this project was transferred to the ONR-ARI on Bubbly Flows. Work completed or initiated during the course of this project to date includes:

(1) Studies of the dynamics of incompressible gas bubbles in time-dependent flows. We have carried out a combination of analytical and numerical studies that have identified conditions for bubble break-up in both steady and time-dependent flows; the influence of bubble deformation on the natural oscillation frequency of various deformation modes; and the onset of chaotic oscillations of shape (that lead to breakup) in both periodic and quasi-periodic flows.

References:

"Small Amplitude Perturbations of Shape for a Nearly Spherical Bubble in an Inviscid Straining Flow (Steady Shapes and Oscillatory Motion)," I. S. Kang and L. G. Leal, *J. Fluid. Mechanics* **187**, 231 (1988).

"Numerical Solution of Axisymmetric, Unsteady Free-Boundary Problems at Finite Reynolds Number. II. Deformation of a Bubble in a Biaxial Straining Flow," I. S. Kang and L. G. Leal, *Phys. Fluids A* **1**(4), 644-660 (1989).

"Bubble Dynamics in Time-Periodic Straining Flows," I. S. Kang and L. G. Leal, *J. Fluid Mech.* **218**, 41-69 (1990).

"Computational Studies of Drops and Bubble Dynamics in a Viscous Fluid," L. G. Leal, Proc. 3rd Int. Colloq. Bubbles and Drops, 147 (1989).

"Bubble Dynamics in Quasi-Time-Periodic Straining Flows," I. S. Kang and L. G. Leal, Proc. Korean-US Joint Seminar on Fluids Eng. and Sciences, 369-380 (1989).

(2) Studies of the dynamics of Rayleigh-Plesset bubbles in time-dependent pressure oscillations Specifically, we have used a simple dynamical systems approach to identify conditions for transition of an ideal gas bubble from regular periodic oscillations of volume in response to periodic pressure fluctuations, to a fully chaotic response. The corresponding sound produced in the far-field is then characterized by broad-band "noise."

Reference:

"The Onset of Chaotic Oscillations and Rapid Growth of a Spherical Bubble at Sub-critical Conditions in an Incompressible Liquid," Andrew Szeri and L. G. Leal, *Physics of Fluids A* **3** (4) 551-555 (1991).

(3) We have initiated studies of the **coupling** between flow, and shape and volume oscillations of an ideal gas bubble. This important topic will include both numerical and analytical studies aimed specifically at understanding conditions for and consequences of resonant coupling between deformation modes and the volume (or "breathing") mode that is responsible for far-field sound. The first comprehensive study of this type has been completed over the past year, using analytical methods to study bubble response to a **pressure impulse**, and a **pressure step**, both in the presence of mean deformation due to flow of the surrounding fluid. We have also worked to refine numerical methods so that they can provide reliable long-time solutions without excessive numerical dissipation.

Reference: "Nonlinear Effects in the Dynamics of Shape and Volume Oscillations for a Gas Bubble in an External Flow" S. M. Yang and L. G. Leal, *J. Fluid Mechanics*, submitted (1991).

Meetings Attended/Presentations 1990-1991

Invited Speaker: Stanley Corrsin Lectureship in Fluid Mechanics, Department of Chemical Engineering, Johns Hopkins University, Baltimore, MD, March 1990.

Invited Speaker: Hydromechanics Colloquium, ONR David Taylor Research Center, Bethesda, MD, March 1990.

Speaker: ONR Workshop on Dynamics of Bubbly Flows, University of Miami, May 1990.

Invited Speaker: NASA Microgravity Fluids Workshop - Cleveland, August 1990.

Seminar: Department of Applied Science, University of California, Davis-Livermore, April 1991.